

Chirality and Cosmic Origins of Life

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Abstract

Chirality or the property that distinguishes lefthandedness from righthandedness is an important aspect of the universe, starting from neutrinos, which are lefthanded. Fifteen years ago the author had proposed that life on the earth was formed through a dual process – several key ingredients being transported from outer space to the earth by comets or meteorites and these in turn interacting with compounds already cooked up in the earth’s seas. Several recent observations point to the fact that the amino acids brought out to the earth by meteorites are lefthanded, as in terrestrial life forms. Experiments in the laboratory however throw up equal numbers of lefthanded and righthanded amino acids, what are called racemic mixtures. Not only would the latest observations endorse this dual mode theory of the origin of life, but on the other hand it would point to the key trigger for life processes itself. This is because racemic mixtures are not optically active, unlike the handed or chiral constituents. It is this activity of harnessing solar radiation and converting it into chemical energy, and storing this in the sugar bonds, as in photosynthesis, that characterizes life.

1 Introduction

Recently there have been some renewed claims that ready made life reached the earth from outer space [1]. For example, R.Joseph and others try to make an elaborate case for life having been transported to the earth from outer

space. These conclusions are at best very speculative and very debatable, if not dubious.

The contention is that life was brought to earth via comets or asteroids, a view propounded by, amongst others Chandra Wickramasinghe and Sir Fred Hoyle. The original idea itself is more than a century old, having been put forward by Arrhenius and others. These ideas went by the name Lithospanspermia. The argument is that microbes could be cold stored as spores and could be brought back to life millions of years hence. All this is within the realm of possibility, but in the absence of unambiguous proof it cannot be treated as being plausible. Undoubtedly, debris produced by supernovae could have bombarded the earth. Footprint on the earth could be the iron and Carbon 12 in ancient rocks that are over four billion years old. But from here to conclude that what was brought down to earth was readymade life itself is a very far cry.

For example let us take the case of the ALH 84001 meteorite which was supposedly ejected from Mars a few billion years ago and fell in the Antarctic region a few thousand years ago. In the mid nineties this meteorite shot into prominence because of claims that it had distinct traces of fossilized micro life, as claimed by Dr. David McKay and a few others. This claim has been contested because similar shapes have been found on terrestrial samples as well. In fact it has been pointed out that these could well be mineral grain deposits. Similar arguments can be put forward in the case of the other carbonaceous chondrites.

On the other hand, the prevailing view that the first organisms were entirely cooked up in the earth's soup may also be far fetched. Francis Crick once noted how improbable this would be. The author suggested in the early nineties that a dual mode origin of life was more likely. That is key ingredients like amino acids, but not yet fully formed life had reached the earth from outer space and chemically interacted with other ingredients present on the earth, to form life [1, 2, 3].

2 A dual mode origin

The basis for these arguments was the observation that several complex molecules have been discovered in interstellar space, for example, in the cool dust clouds of the Orion Nebula and in the constellation of Sagittarius. Observations with telescopes, spectroscopes, radio telescopes and even orbiting

observatories have confirmed the presence of molecules like methyl cyanide, water vapour, formaldehyde, methyl alcohol and even the potable ethyl alcohol. Clearly there are certain organic molecules in the cool dust clouds spread across outer space.

Over one hundred and twenty molecules including those which chemists designate as Methanol and Ethanol, from diatomic molecules through those containing thirteen atoms have been detected in the dark interstellar clouds which are opaque to light. These appear to be nothing less than factories for building complex molecules. The mechanism could be that some of the simpler molecules are frozen in ice droplets which are bombarded by ultra violet radiation from very near by young stars, cosmic rays and ions, all these inducing the formation of very complex molecules by the process of breaking up of molecules and recombination. Interestingly this has been confirmed by simulations on the earth. The polycyclic aromatic hydrocarbons (of aerosol spray and global warming notoriety) under interstellar conditions convert to complex molecules, like alcohols, ethers and quinons. These are ubiquitous in living organisms today, helping in various energy transfer processes like photosynthesis and the ability to absorb ultra violet radiation which is harmful to, for example amino acids. The universe exhibit traces of polycyclic aromatic hydrocarbons. These are the most abundant class of carbons in the universe and may be containing about twenty percent of all the carbon.

This apart the space crafts Giotto and Vega which flew by Comet Halley glimpsed carbon rich molecules while space based observations revealed the presence of Ethane and Methane in Comets Hyakutake and Hale Bopp. Space dust reveals organic carbon. Interestingly some thirty tons of such carbon is brought down to the earth each day by the interstellar dust. Meteorites have shown nucleo basis, ketones, quinines, carboxylic acids, amines and amides. In fact as many as eight of the twenty amino acids involved in life processes have been identified besides some sixty others. This August, NASA announced that an analysis of data from its Stardust mission revealed, for the first time the presence of the amino acid glycine in an icy comet.

Comets which inhabit the cool and dark regions of the solar system definitely contain the building blocks of life. But again, it would be a giant leap of faith, if we say that they contain living organisms. There is increasing evidence through spectroscopic, space craft and even laboratory examinations of debris fallen on the earth, to show that the frozen dirty ice balls, as comets have been characterized, contain not just molecular compounds of carbon, hydrogen, nitrogen and oxygen, but also even more complicated

sugar related substances. Studies at NASA's Ames Research Centre indicate the presence of polyhydroxylated compounds as well. Studies at the Russian Academy of Sciences have confirmed the possibility of abiogenous synthesis of complex organic compounds (monomeric units of nucleic acids) on the surface of comets, asteroids, meteorites and space dust particles in outer space. The presence of sugar related compounds and other complex molecules in meteoritic and cometary objects will support the author's theory of dual origin. It is important to keep the background in mind. Some of these molecules, possibly proteins or amino acids-but not yet living organisms-are very likely to have been transported to earth, and further biochemical reactions would have taken place on the earth itself, with for example fats. Such a hybrid view for the origin of life is consistent with observations and experiments. There are intriguing footprints of outer space on earth based living organisms. The all important amino acids in nature come as left handed molecules and also right handed molecules reminiscent of a right handed spiral conch shell and a left handed spiral conch. The amino acids produced in the laboratory like the Urey-Miller type experiments show equal quantities of the left handed and right handed varieties, which is reasonable. However in life processes, the left handed molecules predominate over the right handed molecules. Interestingly in the amino acids found on meteorites, we have exactly this preponderance of left handed amino acid molecules!

3 The Key Trigger

How can extra terrestrial molecules trigger off chemical reactions leading to the origin of life? Firstly complex molecules containing six or more carbon atoms are known to produce amino acids in warm acidic water, for example on the earth. This apart molecules with as many as fifteen carbon bonds were also created. These molecules form droplet-like capsules. Indeed such capsules, the precursors of cell walls were also exhibited by extracts from meteorites-when organic compounds from these meteorites were mixed with water, they assembled into cell membrane like structures with complex organic compounds. Actually what happens is that these molecules are amphidilic: One of their ends has a preference for water, while the other behaves in an exactly opposite manner. The ends which prefer water form the outer circles of the cell like structures while at the same time hiding within are the inner ends. Such structures could also house other interstellar components,

for example quinons which could harness light and other forms of energy required for life processes.

It appears that amino acids, quinons, amphibilic molecules and the like were transported to the earth by meteoritic dust or cometary fragments. These could well have kick started the first life processes on the earth. But there could be a key trigger as we will see now.

On the face of it, the universe appears to be symmetric, including the left-right symmetry. However a breaking of a symmetry is crucial, as is well known. Thus the neutrinos are lefthanded, that is display chirality or handedness. This refers to the crucial difference between the lefthanded and the righthanded – though mirror images, they cannot be exactly superimposed on each other.

This chirality carries over into the realm of molecules. Such a molecule displaying handedness like the neutrino is called enantiomer. A mixture of equal amounts of two enantiomers, that is lefthanded and righthanded molecules is said to be racemic. The crucial fact is that racemic, that is equally handed mixtures are not optically active. On the other hand separately the enantiomer constituents are optically active.

Optical activity itself arises from the interaction of chiral molecules with polarized light – they can rotate the plane of polarization. Indeed such optical activity carries over to other regions of the spectrum, for example in the microwave region.

It is worth noting that the differently handed constituents of chiral compounds have different properties, an interesting example being that of righthanded sugar (dextrose) and its lefthanded counterpart. Ultimately the differences are due to the chirality inherent in biological system.

As we saw above, the amino acids are chiral and so too are the sugars. It must also be noted that the chirality of life on earth could well be an accident – life on other planets could well have the opposite chirality. What is important is that the mixture of amino acids, which are the building blocks of proteins should not be racemic. This would ensure optical activity in a self-organization context.

Let us consider the above points in a little greater detail. As far as optical activity is concerned, we could think of a racemic mixture as a combination of two polarizers, turned perpendicular to one another, light passing through one is polarized in the x direction let us say. When this passes through the second polarizer this rotated ninety degrees with respect to the first one, then it is completely absorbed.

With regard to self organization, we note that there is a free interplay of solar radiation with the original organic molecules, so that we have to consider open systems and far from equilibrium situations. Let us first start with crystals which to a certain extent mimic life processes. As is well known crystals are ordered arrangements of molecules or atoms which nucleate at certain sites. They can spontaneously grow, and this is a process where the molecules are interacting with one another through forces like Van der Waal interaction. They form bonds, lowering the potential energy in the process. Though ordered, crystals are an example of an equilibrium thermodynamic process. Let us now consider a process of ordering with activity unlike inert crystal. A good example of this is that of the Benard convection cells [4]. As is well known, to realize these cells, let us consider water that is stationary between two plates. When the difference of the temperature between the plates crosses a critical value, highly organized Benard cells are seen to form. However it must be observed that in this case the system is open, in that it receives heat from outside, facilitating the formation of the so called dissipative structures, unlike the equilibrium structures such as crystals, while crystals were a phenomena pertaining to the intermolecular interaction. In this latter case external conditions drive the system away from equilibrium, more quantitatively, the affinity parameter A vanishes for the equilibrium situation, whereas an increase in its magnitude reflects a departure from the equilibrium situation to the non equilibrium regime.

Here in are the seeds of self organization. A key role in these processes is played by auto catalysis leading to a multiplication of certain molecules, as is well known.

There is a further novelty in these far from equilibrium structures, brought out most simply by the well known chemical clock resulting from the $B - Z$ reaction. Here we see that the colours of certain regions change at very regular time intervals. The point here is that the changing of the colours is a bulk phenomenon affecting millions of molecules, which seem to act in unison. In other words there is a new feature, viz., a communication between the molecules.

Let us consider a simple mathematical model in this regard – a random and indefinitely long sequence of a finite number of symbols like 0, 1 or A, B, C , without any constraint on the number of times a symbol can appear in this indefinite sequence. It is always possible to abstract a sub sequence S which repeats itself elsewhere along the line at least once. This would then happen not just twice but several times. Clearly there would be other sub sequences

like S which would also exhibit this behaviour, though one of them may have a greater frequency than the others. Such patterns are always possible in an open system, for example given enough time, energy and material. This recurrent pattern resembles replication. To idealize the situation we could say that if there were N such sequences of a type, then in an average time τ the increase of this number ΔN can be modeled by

$$\frac{dN}{dt} = \frac{\Delta N}{\tau} = \beta N^m \quad (1)$$

where, if τ is sufficiently small compared to the time scales, we could consider the time derivative of N as shown in (1), which leads to

$$N^{(1-m)} = (1 - m)\beta T \quad (2)$$

where T is the total time that is under consideration. For instance in a typical Random Walk type of a scenario m would be half. In any case we can see here the replication and the beginning of communication in the sense of the chemical clock above, remembering that poly nucleotide sequences stored information, given the right conditions. In our mathematical example, the specificity of each of the N sub sequences is itself information. The rest is junk (DNA). Another point to bear in mind is that the conservation of information in polymer sequences distinguishes biological self organization from the chemical counterpart [5].

Ultimately it is the energy of solar radiation on the earth which is converted into chemical energy, and is stored in the bonds of sugar. This is done in algae and plants through the process of photosynthesis.

In recent years, dramatic evidence for this dual mode origin of life has been coming in from different studies. The recent work of Pizzarello in Arizona State University confirms the above scenario. The work of Prof. Ronald Breslow of Columbia University, New York and his coworker M. Levine, for another example. They have found that the predominant left handed amino acids present in the life forms could indeed have been delivered by meteorites from deep outer space, thus seeding life on the earth. This new evidence was found on the surfaces of meteorites which had crashed into the earth in relatively recent times. Dr. Breslow exposed amino acid chemical precursors to the amino acids found on the meteorites and found that these cosmic molecules could transfer their left handedness to the simple amino acids found in life forms. According to Breslow this is the mechanism by

which there is an excess of left handed amino acids in life-even a small excess to begin with could grow in numbers.

Another dramatic confirmation has come in. An important component of early genetic material found in meteorite fragments is extraterrestrial in origin, say scientists from Europe and the USA. They say their research in Earth and Planetary Science Letters provides evidence that life's raw materials came from sources beyond the Earth.

The Materials they have found include the molecules uracil and xanthine, which are precursors to the molecules that make up DNA and RNA, and are known as nucleobases. The team discovered the molecules in rock fragments of the Murchison meteorite, which crashed in Australia in 1969.

They tested the meteorite material to determine whether the molecules came from it were a result of contamination when the meteorite landed on Earth. The analysis showed nucleobases contain a heavy form of carbon which could only have been formed in space-those formed on Earth consist of a lighter variety of carbon.

Lead author Dr. Zita Martins, of the Department of Earth Science and Engineering at London [6] says:

"We believe early life may have adopted nucleobases from meteoritic fragments for . which enabled them to pass on their successful features to subsequent generations.

Between 3.8 to 4.5 billion years ago large numbers of rocks similar to the Murchison down on Earth at the time when primitive life was forming. The heavy bombardment large amounts of meteorite material to the surface on planets like Earth and Mars.

Co-author Professor Mark Sephton, also of Imperial's Department of Earth Science: believes this research is an important step in understanding how early life might have

"Because meteorites represent left over materials from the formation of the solar system components for life-including nucleobases-could be widespread in the cosmos. life's raw materials are discovered in objects from space, the possibility of life spring right chemistry is present becomes more likely."

Even more evidence was unveiled early this year [7] by Professor Akiva Bar-Nun of the Department of Geophysics and Planetary Sciences at Tel Aviv University. He and coworkers found independently that key missing ingredients for life to form in the earth's ancient environ, were available in comets.

. "When comets slammed into the Earth through the atmosphere about four billion years ago, they delivered a payload of organic materials to the young

Earth, adding materials that combined with Earth's own large reservoir of organics and led to the emergence of life," says Prof. Bar-Nun. Specifically Prof. Bar-Nun's work dealt with some of the noble gases in the icy comets. Incidentally, all this means that life would be well spread out in the universe and is not unique to the earth-it could well have formed a few billion years ago on Mars, for instance.

References

- [1] Sidharth, B.G. (2009). *Journal of Cosmology* October 2009, p.73ff.
- [2] Sidharth,B.G. (2002). *Life in the Universe, Proceedings of A.P. Akademi of Sciences*, Vol.6, No.2., 2002.
- [3] Sidharth,B.G. (2006). *Superstition to Supervision* (Sivakameswari, Hyderabad) 2006, pp.74 ff.
- [4] Nicolis, G. and Prigogine, I. (1989). *Exploring Complexity* (W.H. Freeman, New York).
- [5] Schuster, P. (2004). *Solid State Phenomena* Vols.97-98, 2004, pp.27-36.
- [6] Martins,Z, et.al.(2008). *Earth and Planetary Sciences*, 270, Issues 1-2, 2008, pp.130-136.
- [7] Bar-Nun,A.,et al (2009). *Did Comets Contain Key Ingredients For Life On Earth?*, *Icarus*, 201 (1), 2009, pp.406.